10x10 Array of Stimulating Electrode

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INTRODUCTION

Our team was tasked with developing and prototyping an electrode array and integrated display to be used as a sensory substitution and communication device.
The following specifications were given by our client:

- The wearable array must be 4x4 inches at most, and all materials used in its construction must be biocompatible.
- Pre-made electrodes may be used for testing, but the final electrodes used in the design must be concentric ring electrodes fabricated by the team.
- There must be a safety element introduced to the circuitry of the design in order to protect the wearer in the case of an electronic fault.
- The circuitry and LCD display should be able to be fully contained in the designed housing unit and the power may be a wired connection to a wall outlet.
- The LCD display unit chosen should be able to display the pattern of electrodes that are on or off at any given moment.
- When given an input, none to all 100 electrodes should be able to be turned on or off at any given time, in a selected order or pattern.

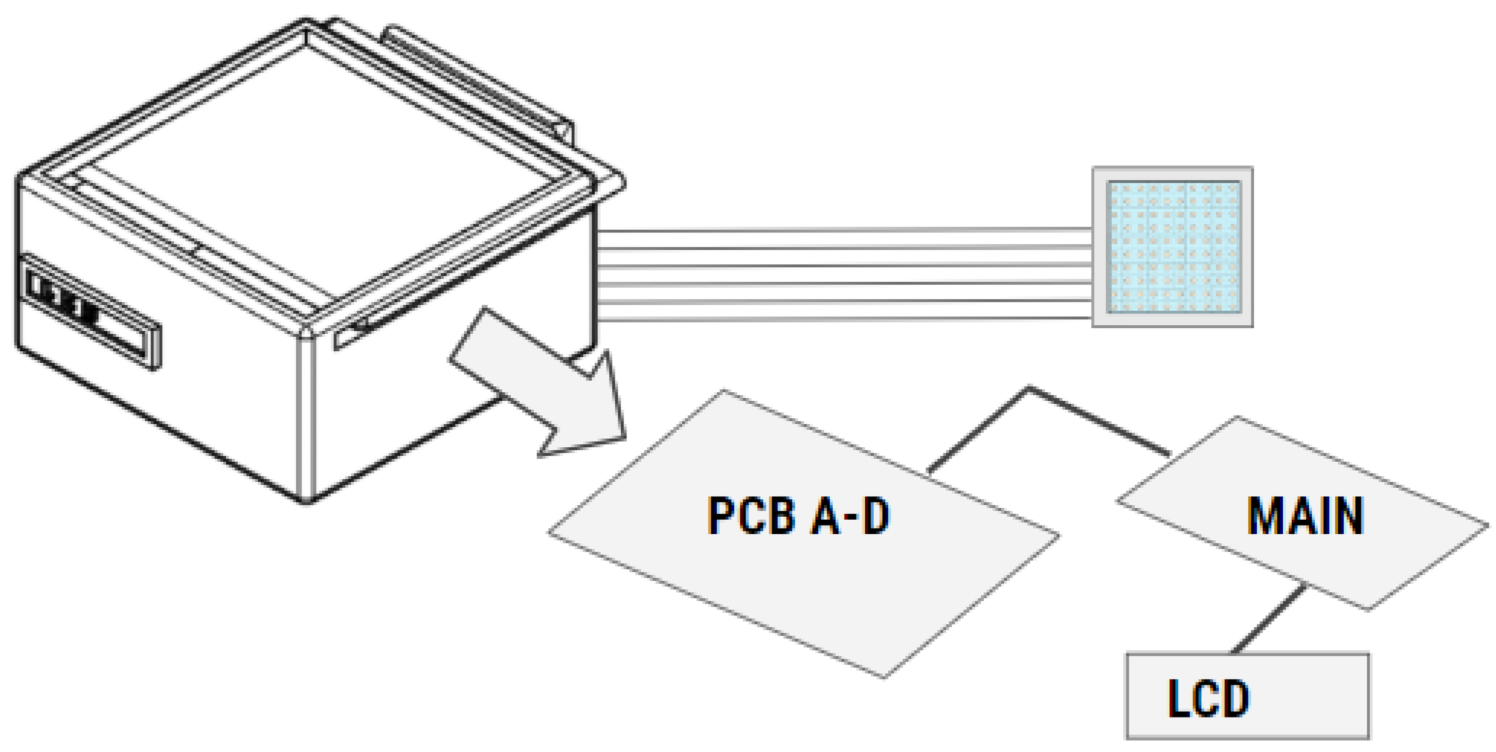


Figure 1. Updated design flow consisting of a housing unit, PCBs, LCD display, and electrode array within a PDMS membrane

METHODS

Electrode Material Testing

We tested several different epoxy resins to be used as insulation in between our stainless-steel rod and tubing.
Epoxy Resins Tested

- GorillaWeld (Failed)
- JB Weld Putty (Failed)
- Flex Seal (Failed)
- Art 'N Glow Casting and Coating Liquid Resin

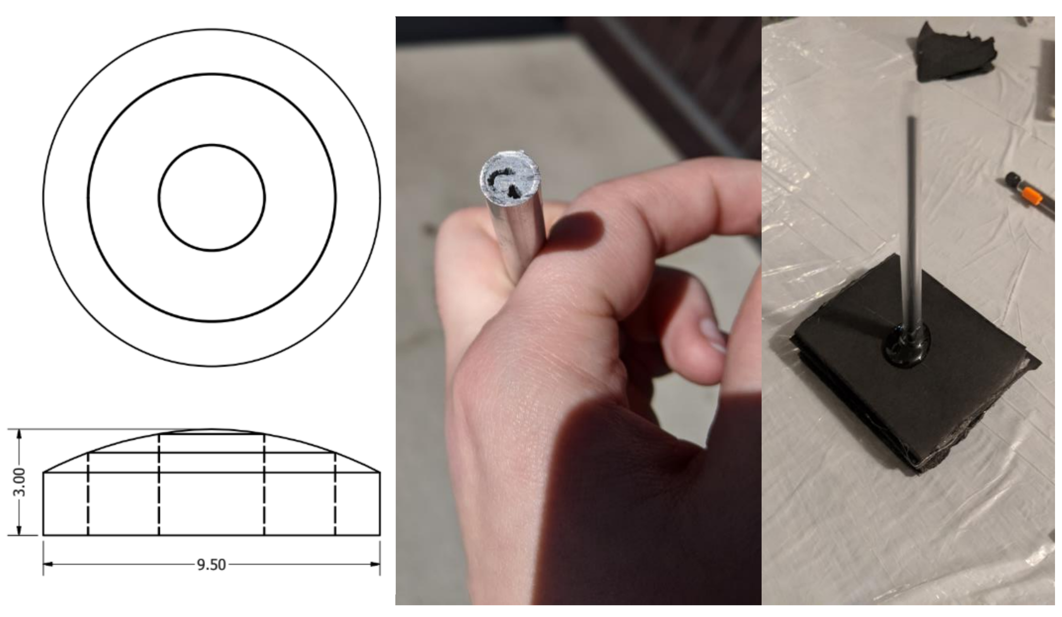


Figure 2.
(a) Updated electrode design.
(b) JB Weld Putty epoxy test result.
(c) Testing apparatus used in material tests.

Breadboard Testing

A scaled down model of our circuitry was tested first a proved to be successful. Our next step was testing the circuit using actual component values, this proved to be successful as well and gave values that matched our PSpice simulations of the circuit with varying skin resistances.

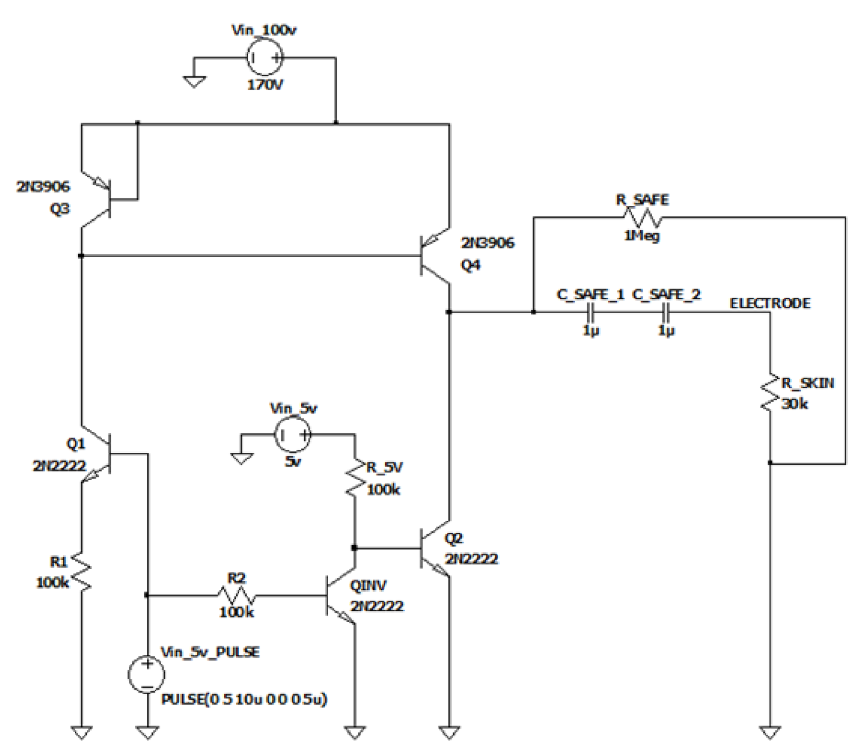
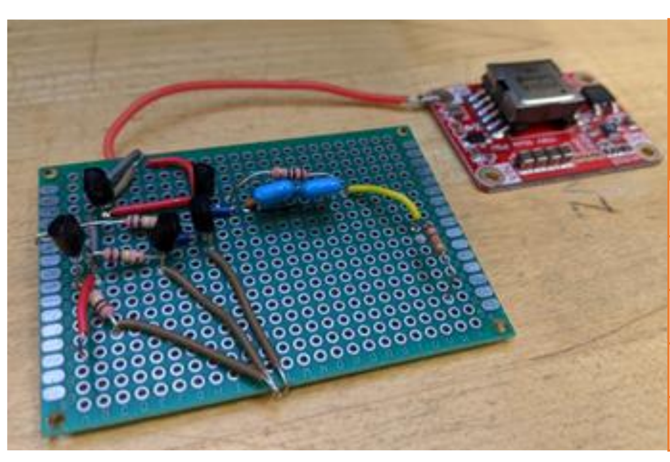


Figure 3. The LTSpice drawing of the stimulation circuitry for a singular electrode. A current mirror was used to keep a constant current regardless of loading. An inverter was also implemented in order to decrease the number of connections between circuitry and microcontrollers.

RESULTS

Protoboard Testing Results

Experimental error has a tendency of increasing as skin resistance increased. Although the experimental error was very high in the upper limits of skin resistance, the max current outputs were still within suitable range for our testing. As skin resistance increased, we also saw a drop in max current output. This was expected as resistance and current are inversely related (Ohm's Law V=IR) and we saw this trend in our simulations as well.



Skin Resistance (kΩ)	Sim. Max Output (mA)	Exp. Max Output (mA)	Exp. Error (%)
1	4.407	4.360	1.062
5	3.764	3.290	12.588
15	2.649	2.467	6.871
22	2.266	1.836	18.990
27	2.058	1.526	25.861

Figure 4. (a) Final protoboard of our stimulation circuitry design. (b) Output currents from the protoboard along a range of skin resistances simulated within our PSpice model as well. These skin resistance values ranged from 1 kΩ to 27 kΩ; experimental errors of max current output were calculated for each trial.

Electrode Fabrication Procedure

1. Using a scrap block of wood, we drilled a hole the approximate diameter of our stainless-steel tubing.
2. Within the center of the same hole, to provide a guide for centering the rod, we then drilled a deeper hole the approximate diameter of our stainless-steel rod.
3. Once both holes were drilled, we placed the rod and tubing in their respective spots.
4. We then mixed equal parts epoxy resin and hardener within disposable plastic cups.
5. Once properly mixed, we poured the resin into the metal tubing being careful to maintain a steady stream to avoid the formation of any gaps or air bubbles.
6. After letting the resin set for a minimum of 72 hours, we removed it from the wood.
7. We then used a belt sander to give the tube a flat face and remove any wood fragments.
8. We beveled the end of the tube at an approximate 45° angle using the belt sander.
9. The tube was secured in a bench vise, and we used a hacksaw to cut off a 3mm section from the beveled end of the tube.
10. The newly cut electrode had a very sharp bottom from the hacksaw, so we very carefully secured it in a small vise grip and sanded it flat on the belt sander.

Figure 5. (a) Final electrode. (b) Final handcrafted electrode vs. dime for scale

Conclusions

Delays in ordering as well as COVID-19 setbacks greatly affected the completion of our project. Overall, we were unable to execute most of our planned design. Because of this, the final product does not meet the client's specifications. However, certain aspects of our design (such as the electrode fabrication and stimulation circuitry) were successful.

Overall, our team was able to finalize an electrode design and construction method as well as find a successful power source solution for the device. The stimulation circuitry also proved to be effective in preliminary and protoboard testing. Unfortunately, we did not get to a point in which we could test the total effectiveness of our design, but successful testing of the individual elements indicates our final prototype would have performed as desired.

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